Verification of the guidance during the period of Typhoon Songda (0418)

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Abstract

As one of the operational meteorological analysis and forecast products, guidance for maximum sustained wind speed (hereinafter referred to as "maximum wind speed") and maximum precipitation has been used to assist forecasters of the Japan Meteorological Agency (JMA) in issuing weather forecasts, warnings and advisories. In this report, practical effectiveness of the guidance for the extreme event was verified, taking an example of the case of Typhoon Songda (0418) which caused considerable damage in Japan. The verification revealed that those guidances were reliable products in a practical level even in this extreme event.

1. Introduction

Japan is a country prone to various kinds of natural disasters, among which tropical cyclone is one of the most devastating events. Since Japan is located in the northwestern edge of the Pacific Ocean, some of the tropical cyclones formed in the tropical or subtropical area go northward and pass through Japan and bring serious natural disasters. Statistically, two or three tropical cyclones make landfall on main islands of Japan in a year, while ten tropical cyclones did in 2004, which hit a new record number of landing tropical cyclones in a year since 1951. Especially, in September 2004, Typhoon Songda (0418) brought extensive damage to Japan mainly due to its strong wind and heavy precipitation.

Tropical cyclone-induced strong wind and heavy precipitation could be extremely hazardous and cause substantial damage. In order to mitigate damage of natural disaster, guidances for strong wind and heavy precipitation were developed by JMA and have been operationally referred to by forecasters to assist them in issuing warnings and advisories to the public in the most timely and appropriate manner.

In this report, an outline of Typhoon Songda (0418) is introduced in section 2, and methods of guidances for strong wind and heavy precipitation are explained in section 3. Prediction by guidances and its verification in the case of Typhoon Songda are shown in section 4 before the conclusion in section 5.

2. Outline of Typhoon Songda (0418)

The best track of Typhoon Songda (0418) is shown in Figure 1. Typhoon Songda was formed near the Marshall Islands on 28 August 2004 and moved northwestward over the Pacific. After passing through Okinawa Islands, the southern subtropical islands of Japan, it recurved northeastward in the East China Sea and made landfall on Kyushu Island, southern main island of Japan, at 00UTC, 7 September. When it landed, the maximum sustained wind speed near the center of the typhoon was 75knots, and the central pressure was 945hPa. After passing through Kyushu Island, it was accelerated by the subtropical jet stream over the Sea of Japan, and then it was transformed into extratropical cyclone over the sea west of Hokkaido, northern main island of Japan, at 00UTC, 8 September.

Wind gust over 50m/s was observed extensively in Japan, setting new records of peak gust at a number of local observatories of JMA. Total amount of precipitation reached more than 900mm at some areas in Kyushu Island and storm surges were also observed along many coastal areas.

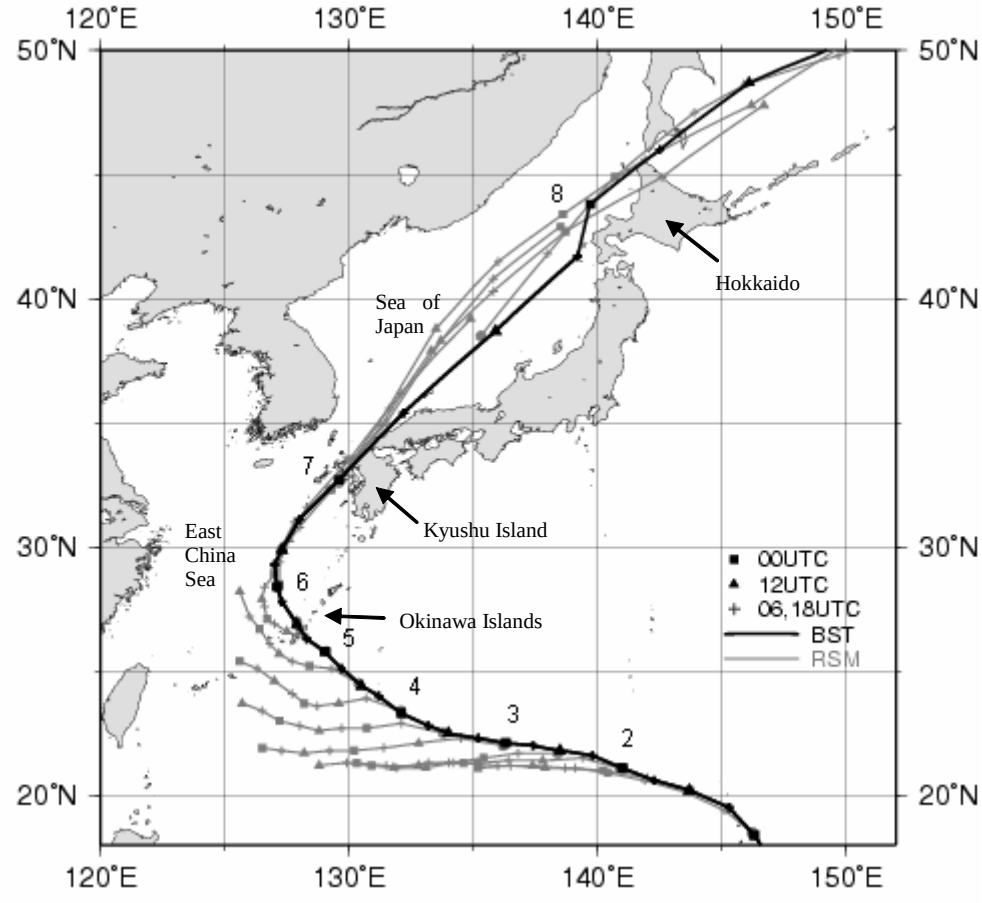

Figure 1 The best track of Typhoon Songda (0418) (black line) and predicted typhoon tracks by RSM at each initial time (gray lines). Six-hourly typhoon positions are plotted. Numbers indicate the dates of September 2004 showing typhoon's positions at 00UTC.

3. Methods of guidance

Guidances for maximum wind speed and maximum precipitation are operationally generated twice a day by JMA, using the output based on the statistical relation between the Regional Spectral Model (RSM) model output and observations. RSM runs twice a day with the initial time of 00 and 12UTC, covering East Asia, and predicts up to 51 hours from the initial time. The details of RSM can be referred to in JMA (2002a). Remarkable advantages of the guidance method are that they can eliminate systematic errors in model output and can represent elements which numerical model cannot predict directly (Wilks, 1995). Specifications of the respective guidances are listed in Table 1.

Table 1 Parameters of guidances

Output	Maximum wind speed and its direction	1-hour and 3-hour maximum precipitation	24-hour maximum precipitation
Initial Time	00, 12 UTC		
Forecast Hour	FT = 03-06, 06-09, …, 48-51		FT = 03-27, 09-33, 15-39, 21-45, 27-51
Input	Regional Spectral Model Output		
Points / Zones	855 AMeDAS* points	362 forecast zones	

*Automated Meteorological Data Acquisition System

A: Maximum wind speed guidance

The maximum wind speed guidance gives maximum value of sustained wind speed and its direction at 3-hour intervals at each observation station. Predictor variables of this guidance are horizontal wind components at 10m above the ground predicted by RSM.

The prediction equations are as follows:

$$U = Um + X1 + X2 * Um + X3 * Vm \qquad V = Vm + X4 + X5 * Um + X6 * Vm$$

where U and V are eastward and northward components of maximum wind speed guidance, respectively. Um and Vm are those of RSM output. X1 through X6 are coefficients which are updated twice a day by Kalman Filtering method. With Kalman Filtering method, the most likely estimation which minimizes the expected root mean square error is obtained. However, the output has a tendency of lower frequency for rare events such as strong wind and heavy precipitation than actually observed data. To correct this bias, the calculated values are rescaled by the “frequency bias correction scheme” (JMA, 2002b).

B: Maximum precipitation guidance

Ebihara (2003) describes the details of the maximum precipitation guidance. There are 362 forecast zones, approximately 1,000km^2 wide each on average, for warnings and advisories issued in Japan. The guidances for maximum precipitation for 1 hour, 3 hours and 24 hours are calculated for each 362 zone. The guidance is composed of mean precipitation amount and the ratio of maximum/mean precipitation amount. Both are estimated for each zone and valid-time period. Mean precipitation is estimated by Kalman Filtering method. Coefficients of each term in regression model are re-estimated twice a day by the method. Maximum/mean precipitation ratio is estimated by artificial neural network.

Accuracy of maximum/mean precipitation ratio depends on mean precipitation amount. When mean precipitation amount is small, this ratio widely varies according to atmospheric conditions. In the contrary case of large mean precipitation amount such as the case of typhoons, the ratio usually converges into a single value. Therefore, maximum precipitation amount is linearly dependent on mean precipitation amount. In this case, accurate estimation of mean precipitation will lead to accurate estimation of maximum precipitation.

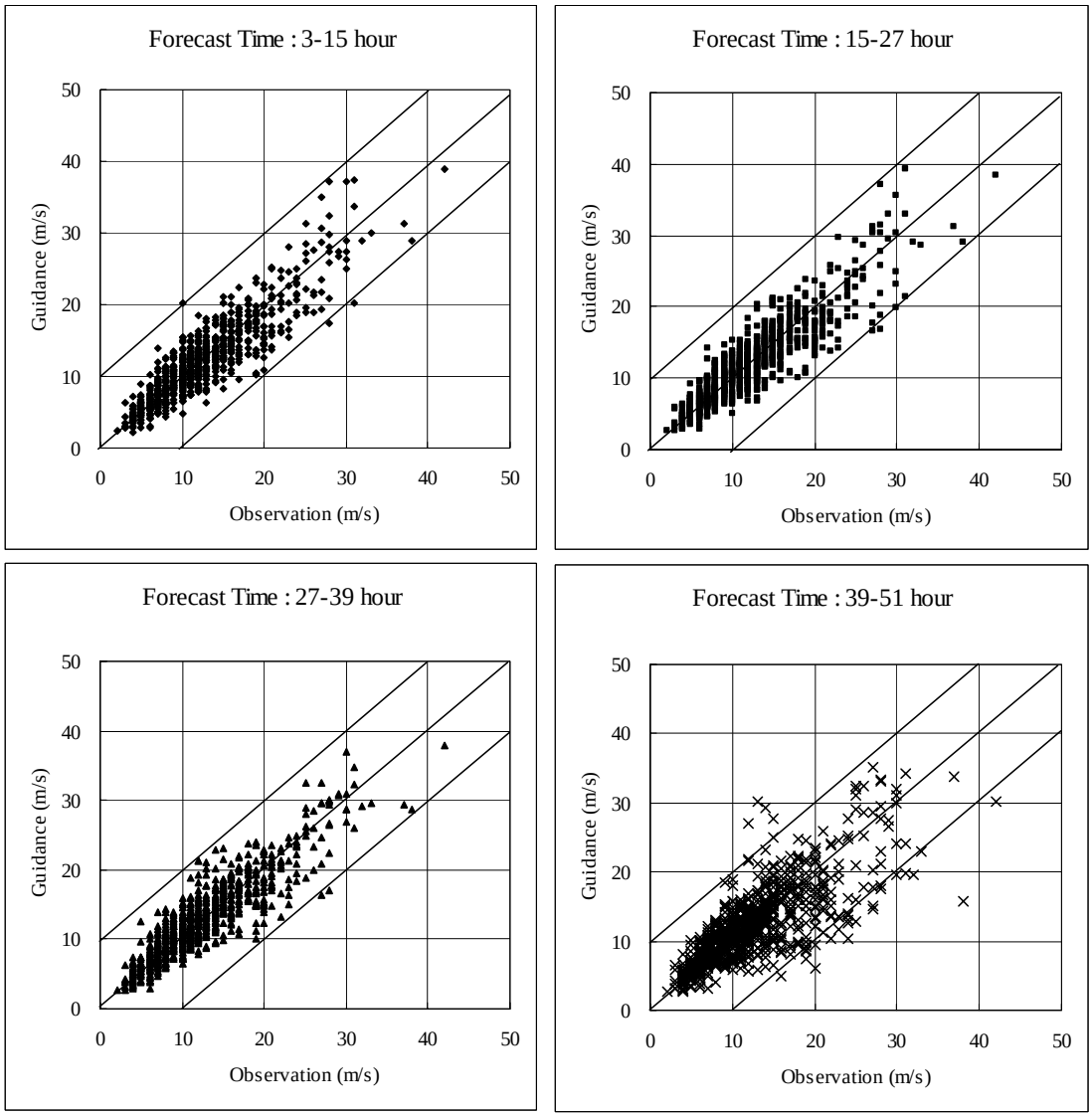

Figure 2 Scatter diagram of the maximum wind speed of the observation and that of guidance. Upper left is for FT=03-15, upper right is for FT=15-27, lower left is for FT=27-39, and lower right is for FT=39-51.

4. Prediction of strong wind and heavy precipitation by guidance and its verification in the case of Typhoon Songda (0418)

Figure 1 shows the best track of Typhoon Songda (0418) and predicted tracks by RSM. RSM predicted with an apparent westward error before the recurvature, followed by fairly good predictions during and after the recurvature.

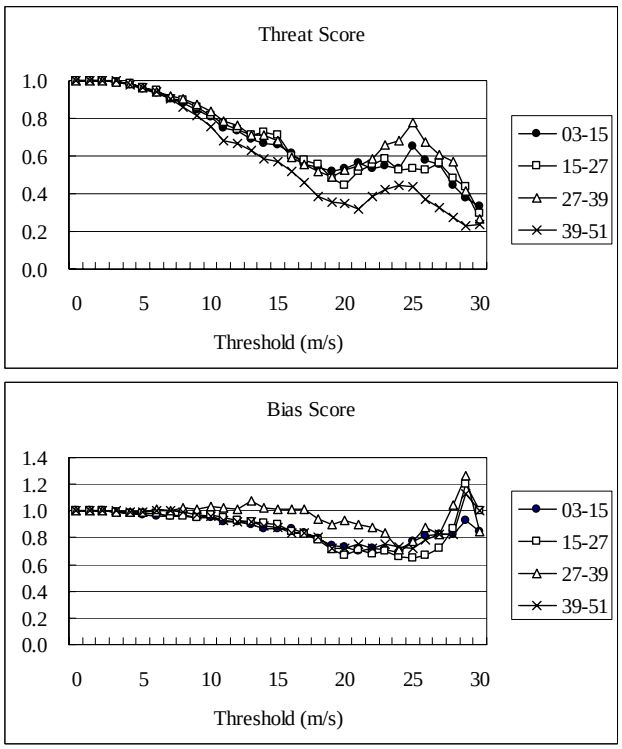

Figure 3 Threat score (upper) and bias score (lower) of the maximum wind speed guidance. Horizontal axis shows threshold wind speed.

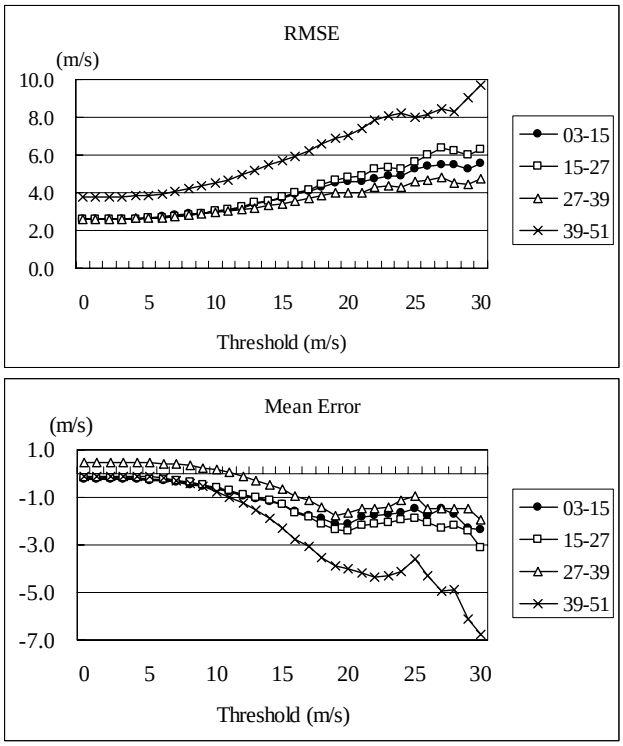

Figure 4 Root mean square error (upper) and mean error (lower) of the guidance. Horizontal axis shows threshold wind speed.

A: Maximum wind speed guidance

The maximum wind speed guidance during the period of Typhoon Songda was verified.

The observed maximum wind speeds from 4 to 8 September 2004 were compared with those by the guidance at each corresponding period. The maximum wind speed recorded during this period is assumed to be caused by Typhoon Songda at every observation point, because Songda moved along the Japanese Archipelago. The averaged time difference between observed time and predicted time by the guidance is no more than 6 hours.

Figure 2 shows scatter diagrams of the observed maximum wind speeds and those by the guidance for various forecast time ranges. The error of the guidance becomes clearly larger as the forecast time becomes longer. However, it should be noted that most of the absolute errors remain within 10m/s and no systematic bias is found in the figure.

Threat score and bias score of each threshold wind speed are shown in Figure 3. Horizontal axis indicates threshold wind speed. Threshold wind speed means that the score is calculated for the cases in which observed wind speed is more than the threshold value. Threat score of maximum wind speed guidance is 0.5 or more even if threshold wind speed is 20m/s except for 39-51 hours forecast. Bias score of the guidance where threshold wind speed is 20m/s is about 0.7 except for 27-39 hours forecast. The bias score less than 1.0 means that the frequency of the strong wind predicted by the guidance is less than actually observed.

Figure 4 shows root mean square error (RMSE) and mean error (ME) of the guidance. RMSE is about 5m/s for the threshold wind speed of 20m/s except for 39-51 hours forecast. The number of cases in which observed wind speed is more than 20m/s is about 100. RMSE increases as the threshold wind speed increases, however, the increase of RMSE is small except for 39-51 hours forecast. ME is about -2m/s for the threshold wind speed of 20m/s except for 39-51 hours forecast.

One of the reasons the wind speed prediction of the guidance was satisfactory was that the track of Typhoon Songda was fairly well predicted by RSM after the recurvature as shown in Figure 1.

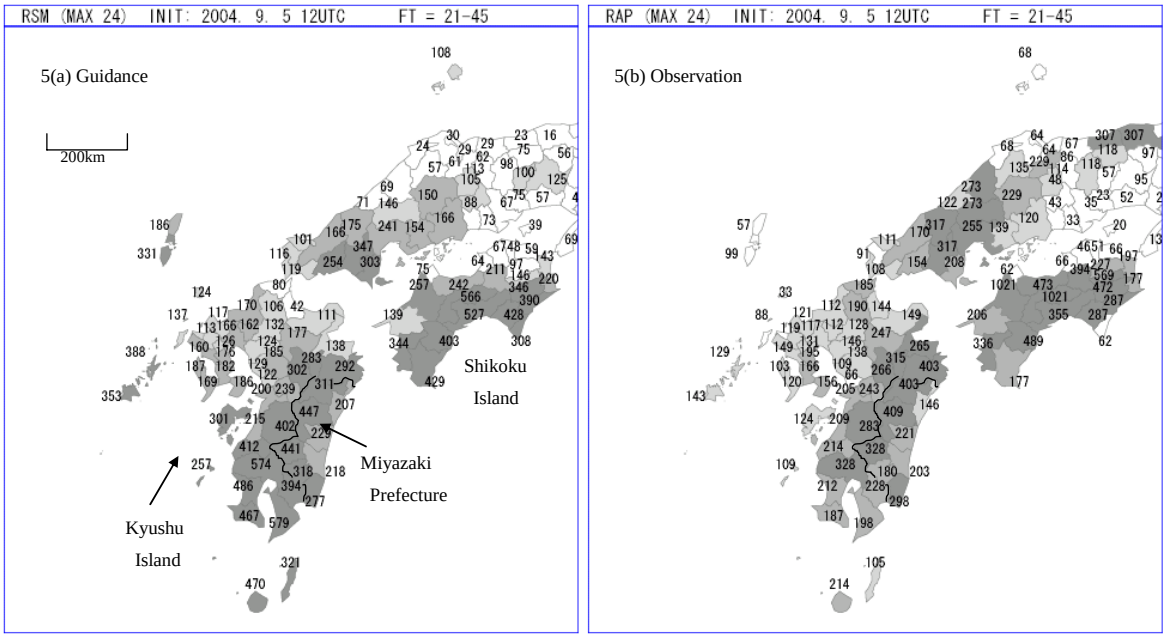

Figure 5 Spatial distribution of 24 hours maximum precipitation (unit: mm/24 hours) in each zone from 09 UTC, 6 September to 09UTC, 7 September in western Japan: (a) maximum precipitation guidance (initial time: 12UTC, 5 September) and (b) Radar-AMeDAS precipitation (analyzed precipitation using radars and raingauges).

B: Maximum precipitation guidance

In this report, discussion is focused on the maximum precipitation guidance for 24 hours as it characterizes the typhoon precipitation.

Figure 5(a) shows an example of maximum precipitation guidance in the western part of Japan. Its initial time is 12UTC, 5 September and forecast time is 21-45 hours. Predicted track of the typhoon by RSM is fairly good at this initial time (Figure 1).

Extremely heavy precipitation more than 400mm/24hours is predicted in some forecast zones, especially in the southern part of Kyushu and Shikoku Islands, where the south-easterly wind around the north eastern part of the typhoon hits directly on mountains. In these areas, heavy rain warning is issued when precipitation more than 200-300mm/24hours (threshold varies with the zone) is predicted. This guidance was available at 16UTC, 5 September well before the landfall of Typhoon Songda on Kyushu Island, which means that these warnings can be issued well in advance with sufficient lead time.

In Miyazaki Prefecture, southeastern part of Kyushu Island, relatively small amount of precipitation slightly more than 200mm/24hours is predicted in the coastal zones, while much more precipitation is predicted along the mountains. It is found that maximum precipitation guidance can express such difference reflecting local topography. Figure 5(b) shows Radar-AMeDAS analyzed precipitation derived from the radar and raingauges observations in the same period as Figure 5(a). Observed precipitation also has local topographical distribution and it corresponds well to the predicted guidance. Scatter diagram between guidance and observed precipitation is shown in Figure 6. There is a close correlation between the

guidance and observation, although guidance for a few forecast zones is far underestimated. This guidance is found to be a very useful product to assist the forecasters in issuing typhoon information.

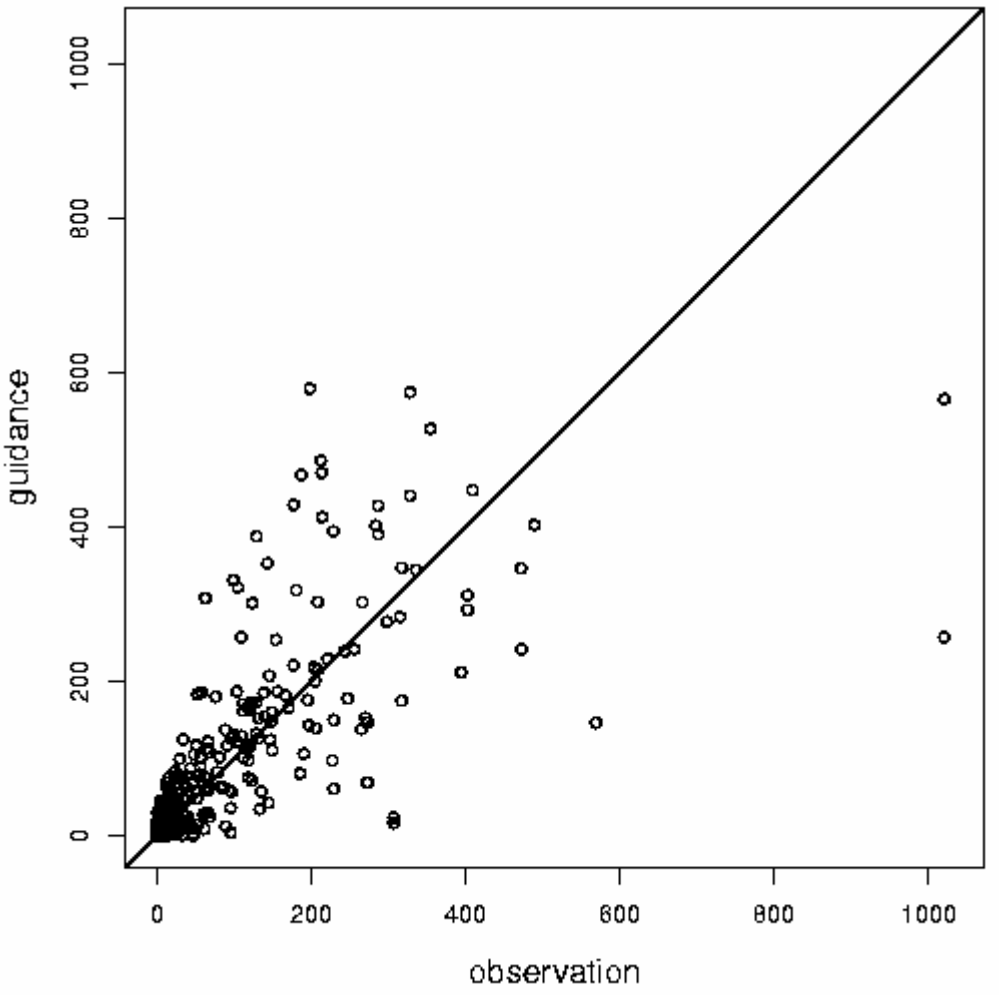

Figure 6 Scatter diagram of 24 hours maximum precipitation of guidance and observation (unit: mm/24hours). Initial time and valid time are same as Figure 5. One circle corresponds to one forecast zone and all 362 zones in Japan are plotted.

5. Conclusion

Guidance for maximum wind speed and maximum precipitation was verified during the period of Typhoon Songda (0418).

For the threshold wind speed of more than 20m/s, threat score and bias score of maximum wind speed were mostly about 0.5 and 0.7, and RMSE and ME were mostly about 5m/s and -2m/s, respectively.

Guidance for maximum precipitation represents very heavy rainfalls with the precipitation more than 400mm/24hours. Although observed precipitation was more than the predicted amount by the guidance at some areas, the guidance illustrates the topographic distribution of precipitation, such as in costal zones and areas along the mountains.

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